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Southwestern Riparian-Stream Ecosystems:

Research Design, Complexity, and Opportunity

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ABSTRACT

Two basic approaches to research design in riparian areas—intrastream and interstream—and their merits are evaluated based on physical, chemical and biological data from streams in central Arizona and northern New Mexico. Interaction between research and management personnel must be constant and close to identify research opportunity. Such a partnership operating within the framework of daily forest land management activity will be effective in generating valid, defendable, and applicable information for future management of forest lands.

Conducting viable research on the effects of the combination of natural- and land management-induced factors on stream environments and biota in southwestern National Forests is complex. Factors contributing to complexity are: (1) interactions of multiple land uses, (2) spatial-temporal relationships, (3) inability to establish a frame of reference, (4) inability to replicate study areas, (5) jurisdiction in habitat and species management, and (6) frequent changes in land management objectives and direction. Combined, these factors render it difficult to effectively study land management impacts on riparian ecosystems.

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INTRODUCTION

National Forest lands cover more than 21 million acres in Arizona and New Mexico. Topographically, these lands are typically upper elevation (> 1,500 m) and are the coolest and best-watered areas in the predominantly arid and semiarid Southwest. Because of the relatively greater annual precipitation (> 31 cm annually), extensive harvestable stands of conifer forests flourish. Livestock graze on herbaceous forage over more than 75% of all National Forest lands in the Southwest. In addition, these lands have sustained timber harvest for over three quarters of a century. In these upland, more mesic areas, streams support both wild and put-and-take populations of trout and other wild, native fishes.

Montane streams and surrounding riparian ecosystems comprise less than 1% of the forest landscape. Research on the structure and functioning of these valuable natural resource areas in montane areas in the Southwest is both complex and in its infancy (Rinne 1985). For example, until recently, most studies relating the interactions of grazing and fisheries have been descriptive, popularized, and have lacked scientific approach and proper study design (Platts 1982; Rinne 1988a, 1989; Szaro and Rinne 1988). Further, the effects of livestock grazing on riparian ecosystems, water quantity and quality, stream dynamics, and fish populations have been sparsely quantified and documented. The combined effects of land use practices and natural events on stream habitat and fisheries interactions have become the topic of increased research in the last decade. However, most research effort on the effects of grazing on riparian ecosystems, for example, has been in the northern Rocky Mountain and Great Basin Provinces (Kauffman and Krueger 1984).

Between 1982 and 1985, research was initiated on a single and two locally contiguous groups of montane streams in central Arizona and in northern New Mexico (fig. 1). In 1982, research commenced on the Rio de las Vacas, Santa Fe National Forest. The primary objective of the study was to determine if a decade of grazing exclusion was beneficial to riparian stream habitat and fishes. This riparian area was previously (1973–75) fenced to eliminate livestock grazing. Fencing design precluded unequivocable conclusions from research (Rinne 1988a). Because of apparent shortcomings, a cursory, interstream study was also initiated on the Rios Capulin and Nambe and the Santa Fe River north and east of Santa Fe, New Mexico. Finally, in 1985 another interstream study was initiated on six streams draining the Mogollon Rim in the Tonto National Forest to establish baseline data to examine the effects of proposed changes in grazing management. Data were collected on fishes, their habitats, and their food source (macroinvertebrates) in streams draining watersheds either subjected to or restricted from general multiple uses, such as grazing, timber harvest, and recreational activity and fishing.

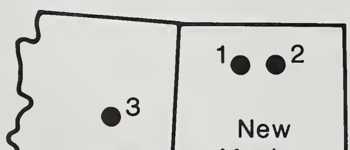

Figure 1.—Location of Rio de las Vacas (1), Santa Fe River (2), and Mogollon Rim (3) study areas.

Results of research on these riparian-stream ecosystems were not always what had been anticipated. Study results demonstrated (1) that land managers should not expect quick, broad-scale solutions to resource problems, and (2) that researchers interacting with personnel from all forest disciplines must be vigilant of research opportunities and exceedingly perceptive in study design to provide meaningful information for effective land management. This paper (1) points out the complexity of the relationships that must be considered when selecting and designing studies of the functioning of and interactions within riparian ecosystems, (2) discusses the merits of the two potential approaches to study design for riparian ecosystems, and (3) emphasizes the need for research and management personnel to interact closely and continually to discern opportunity for studies that will provide answers for land management problems.

STUDY AREAS

Three separate study areas were examined (fig. 1). The first was a single stream, the Rio de las Vacas, a third-order montane stream draining the San Pedro Parks Wilderness Area, Santa Fe National Forest, New Mexico. Study area descriptions and livestock grazing history are in Szaro et al. (1985) and Rinne (1988a). The second area included three streams. The Santa Fe River is a second-order stream in the Sangre de Cristo Mountains of northern New Mexico serving as a primary water supply for the city of Santa Fe. To ensure high water quality, the watershed has been closed to normal multiple uses since the 1930's. The Rio Nambe and Rio Capulin are first-order streams having their source on the same mountain as the Santa Fe River, but drain north-northwest on its opposite side. Both watersheds are sub-

ject to normal National Forest land uses. Steep mixed conifer slopes border all three streams.

The last area, a group of six streams, lies below the Mogollon Rim in central Arizona. Six perennial first-order streams (Pine, Dude, Bonita, Ellison, Christopher, and Horton creeks) issue from a major fault block (Rinne and Medina 1988). Historically, these watersheds have been subjected to varied grazing and timber management practices. Pine Creek, at one end of the use spectrum, has not been grazed or logged for 25 years. In contrast, the Horton Creek watershed has been grazed season-long and continuously (May–October), and timber has been harvested on the watershed for years. The other watersheds are within grazing allotments and timber management areas that fall between these two extremes. Studies were initiated to establish baseline information to evaluate proposed changes in grazing management.

In June 1990, a 10,000-ha natural wildfire (the Dude Fire) dramatically altered three of the six watersheds in this area. This natural event combined with eventful pretreatment data provided an excellent opportunity to evaluate natural and artificial effects on the structure and functioning of riparian areas.

The Rio de las Vacas supports three native and at least two introduced species of fishes (Rinne 1988a). Because rainbow and the native cutthroat trout hybridize, the Santa Fe River and Rios Nambe and Capulin contain both native cutthroat and introduced rainbow trout and their hybrids. All streams but the Santa Fe River are subject to sport fishing. The Mogollon Rim streams contain only introduced salmonids in varied assemblages (Rinne and Medina 1988).

Figure 2.—Streambank vegetation along reaches of stream in ungrazed (upper) and grazed (lower) areas of the Rio de las Vacas.

METHODS

Fish numbers and biomasses were estimated by electrofishing blocked 50-m sections of stream three times (Rinne 1978). Water quality was analyzed by standard field water quality kit, streambank deterioration was estimated followed methods of Binns (1982), and streambank vegetation and overhanging vegetation were measured with a meter tape. Aquatic macroinvertebrates were collected by Surber sampler, sorted, and identified in the lab; Biotic Condition Indices were then calculated using methods of Winget and Mangum (1979).

Research Design

Intrastream Approach

This research approach was taken to study the effects of grazing on fish populations and their habitats in the Rio de las Vacas. Rinne (1988a) reported findings on fishes, and results will only be referred to here. Physical habitat structure in the Rio de las Vacas was dramatically different between grazed and ungrazed reaches of stream (Rinne 1985; fig. 2). Streambank vegetation and overhanging vegetation were much greater in the ungrazed compared to the grazed reaches. Bank instability varied from 20% to 100% in grazed areas; banks were totally stable in the exclosed areas. Stream substrate permeability and flow were less in the grazed areas (Rinne 1988a).

Initially, the intrastream approach on the Rio de las Vacas appeared to be desirable to control variation in data estimates. However, although a stream and its associated riparian habitat are usually a well-defined narrow band of habitat within the forest landscape, functionally the converse is true. Streams are dynamically interrelated with and affected along their entire length by their watersheds (Hynes 1975, Platts 1979, Triska et al. 1982). Accordingly, a given reach of stream such as that exclosed in the Vacas is not functioning independently, but rather is affected cumulatively by not only upstream and downstream reaches (Vannote et al. 1980), but by land uses on the watershed.

For example, water samples collected in summer 1984 in an upper ungrazed reach (sample section 3; fig. 3) indicated the presence of significantly higher nutrient (phosphates, nitrates, and sulfates) content than in samples from a downstream reach (section D) sampled the next day (table 1). Because of these differences, additional samples were analyzed two days later from the same upstream locality (sample section 3). Nutrients were no longer detectable, but hardness had increased

Figure 3.—A detailed map of the Rio de las Vacas study area indicating 50-m study sections in the upstream grazed (F-I) and ungrazed (1-6) areas and the downstream grazed area (A-E).

significantly. Heavy recreational use above the study area involving several hundred campers on a holiday weekend was apparently responsible for the short-term, highly variable nutrient concentrations.

Numbers of fish among study sections in the Vacas were likewise highly variable in 1982 (Rinne 1985, 1988a). In ungrazed reaches of stream, 86–95% of the fish and 51–75% of total biomass were comprised of suckers and chubs. By comparison, these nonsalmonid taxa contributed 95% or more of total number and biomass in the grazed area. Numbers of fish were greater in the grazed area, but similar biomasses in the two areas reflected the larger mean size of fish in the ungrazed reaches.

Conceivably, the obvious benefits accrued to fish habitat in the reaches of stream within nongrazed reaches were dampened by the negative effects upstream. In context of the river continuum concept, the length of stream benefited (2 km) was not sufficient to produce a significantly positive effect on salmonid populations in the Vacas. Platts and Nelson (1985) reported this same spatial-linear influence in a Utah stream.

Aquatic macroinvertebrate analyses indicated marked differences between exclosed and grazed areas (Rinne 1988b). However, because of lack of background pretreatment data, these differences could be as easily attributed to natural, linear changes in stream morphology, water quality, and to increased solar radiation because of less streamside vegetation. Although several tolerant taxa were more abundant in grazed areas than in ungrazed areas, relative densities and biomasses of macroinvertebrates and BCI did not consistently fit what would be expected in the two differently treated areas.

Interstream Approach

In keeping with the idea that watershed management impacts a stream (Hynes 1975), data on fish populations were collected from streams situated within paired watersheds that have been managed differently for a considerable period of time (tables 2–3). This interstream or watershed approach was taken to determine the feasibility of such a design in discerning land use impacts on stream habitat and fishes. Two areas were examined in New Mexico and one in Arizona (fig. 1).

New Mexico.—Fish population numbers in study section 1 in the Santa Fe River were comparable between 1982 and 1983, but increased 43% in numbers and 96% in biomass between years in section 2 (table 2). Study

Table 1.—Selected water quality estimates (all in mg/L) in the Rio de las Vacas, June 1984. Ranges are in parentheses. t-Values and significance (*0.05, **0.01) between Sunday (6/24) and Tuesday (6/26) measurements are shown.

Date	Time	Study section	*n*	Nutrients			Alkalinity	Hardness		
				PO_4	NO_3	SO_4		CA	MG	Total
6/24/84	1245	3	10	0.18 (0.14–0.21)	1.26 (0.95–1.65)	2.7 (1.0–6.0)	112.8 (110–120)	85.6 (80– 90)	97.5 (91–100)	183.1 (179–190)
6/25/84	1100	D	10	0.007 (0.003–0.13)	0.15 (0.05–0.25)	1.8 (1.0–3.0)	131.3 (121–140)	96.4 (92–100)	109.7 (103–116)	206.1 (190–211)
6/26/84	1200	3	10	0	0	0	110.2 (104–115)	94.2 (91–100)	106.4 (100–112)	200.6 (194–210)
t-Statistic				8.19**	13.04**	1.24**	2.69	1.13	3.6**	11.53**

Table 2.—Comparative fish numbers and biomasses in the Santa Fe River, and Rios Nambe and Capulin, 1982–1984.

Stream	Year	Section	Number per 50 m	Number per km	Biomass g/50 m	Biomass kg/km
Santa Fe River	1982	1	40	800	1,052	21.0
		2	40	800	1,423	28.5
	1983	1	36	720	1,110	22.2
		2	57	1,140	2,786	55.7
Mean				865	1,593	31.9
Rio Capulin	1983	1	50	1,000	1,092	21.8
	1984	1	38	760	1,340	26.8
		2	35	700	1,165	23.3
		3	19	380	801	16.0
Mean				710	1,100	22.0
Rio Nambe	1983	1	37	740	1,117	22.3
	1984	1	23	460	1,626	32.5
		2	8	160	394	7.9
Mean				453	1,046	20.9

Table 3.—Preliminary fish statistics in Mogollon Rim streams based on samples of 50-m sections of stream. Relative ranks from highest to lowest are shown in parentheses after statistics.

Stream (n)[1]	Summer	Number of fish/km	Biomass (kg/km)	Fish density n/m^2	Fish density g/m^2	Mean length of fish (cm)	Mean weight of fish (g)
Pine (5)	1985	1,500 (2)	54.8 (2)	0.53 (1)	15.0 (2)	14.6 (3)	36.5 (4)
	1986	1,396 (2)	38.9 (4)				
Horton (7)	1985	680 (3)	46.2 (3)	0.12 (5)	11.8 (3)	16.2 (1)	70.0 (1)
	1986	350 (4)	39.0 (3)				
Christopher (2)	1985	2,780 (1)	66.4 (1)	0.46 (2)	15.2 (1)	11.6 (5)	23.9 (5)
	1986	1,853 (1)	60.3 (1)				
Ellison (2)	1985	290 (4)	6.0 (6)	0.27 (3)	6.9 (4)	10.8 (6)	11.1 (6)
	1986	533 (3)	13.8 (4)				
Dude (2)	1985	200 (6)	10.6 (4)	0.16 (4)	6.2 (5)	15.9 (2)	48.0 (2)
	1986	302 (5)	12.0 (4)				
Bonita (2)	1985	210 (5)	8.5 (5)	0.08 (6)	5.1 (6)	14.3 (4)	40.6 (3)
	1986	152 (6)	10.7 (2)				

[1] *Number of 50-m sections.*

section 1 in the Rio Capulin decreased 25% in fish numbers between 1983 and 1984, but biomass increased 23%. Number of fish in study section 1 decreased almost 40% from 1983 to 1984 in the Rio Nambe, but biomass increased 46%.

Fish populations in the "quasi-pristine" Santa Fe watershed were not significantly greater than in the Rios Nambe and Capulin—watersheds under normal multiple use management. In an interstream analysis approach, the question of comparability of watersheds immediately arises. The three streams are contiguous; they head on the same mountain. However, geologic strata, watershed exposure, and vegetation may be different. The most obvious difference is that sport fishing is prohibited on the Santa Fe River but occurs on the Rios Nambe and Capulin. Indeed, one might expect greater fish populations in the Santa Fe. Although average fish numbers and biomass in the Santa Fe River were higher than in the other two streams (table 2), natural variation (see Platts and Nelson 1988) and sport fishing effects cannot be adequately defined by such brief sampling (Platts 1981).

Arizona.—Based on mean widths and summer low flows, the six Mogollon Rim streams are grouped into three larger (Pine, Horton, and Christopher) and three smaller (Bonita, Ellison, and Dude) creeks (table 4). Summer water temperatures were slightly warmer in two of the streams (Dude and Bonita). Chemically, all streams are similar except Pine Creek, which displayed the highest specific conductance, alkalinity, hardness, and dissolved oxygen.

Overall, fish number and biomass per kilometer followed stream size (table 3). However, Christopher and Pine Creeks ranked ahead of the larger Horton Creek in

Table 4.—Physico chemical characteristics of Mogollon Rim streams in summer 1985. Temperature, pH, dissolved oxygen, and specific conductance are based on 24-hr data (ranges in parentheses); the remainder of parameters comprise 5 samples each. Mean widths are derived from 10 measurements and flows from 5 estimates.

Stream	Date	Temperature (C)	pH	Dissolved oxygen (mg/L)	Specific conductance (mmhos)	Mean width (m)	Nutrients (mg/L)			Flow m^3/min	Total alkalinity (mg/L)	Total hardness (mg/L)
							PO_4	NO_3	SO_4			
Pine	6/27	13.8 (11.2–16.4)	7.8 (7.7–8.0)	8.6 (8.0–9.8)	278 (269–285)	2.6	0.19	1.01	4.2	1.66	132	171
Horton	6/24	14.6 (10.9–19.4)	7.9 (7.6–8.3)	8.1 (7.4–9.0)	237 (234–240)	3.1	0.36	1.04	14.6	5.65	129	165
Christopher	6/26	11.5 (9.3–15.2)	7.7 (7.6–8.0)	8.6 (8.1–9.1)	231 (229–232)	4.0	0.38	1.03	17.8	2.39	88	149
Ellison	7/23	14.6 (13.1–16.1)	7.5 (7.4–7.6)	7.6 (7.2–8.0)	211 (209–217)	2.0	0.16	0.66	2.6	0.28	87	140
Dude	7/20	16.9 (14.6–20.1)	7.8 (7.7–8.1)	7.7 (7.0–8.0)	251 (245–254)	2.0	0.24	0.83	3.4	0.37	105	158
Bonita	8/6	15.0 (13.0–17.7)	7.8 (7.7–7.9)	8.4 (7.7–9.5)	239 (234–250)	2.1	0.39	0.70	1.2	1.12	120	149

these statistics and in trout density (number and grams per square meter). Based on mean length and weight of fish, Horton Creek lacked smaller individuals, perhaps reflecting reduced spawning success in that stream.

Average Calculated Biotic Condition Indices for aquatic macroinvertebrates were highest (83) in Christopher; identical in Pine, Horton, and Bonita creeks (74–75); and least in Dude (66) and Ellison (57) creeks. A water penny (genus *Psephenus*) that may be an indicator of reduced substrate fine sediments (Usinger 1956:365) was collected only in Pine Creek. The presence of water penny, greater trout density and biomass in Pine compared to Horton, and apparent lack of trout reproduction in Horton may indicate increased substrate fines in Horton. Nevertheless, stream size based on mean width and flow appears to largely influence fish numbers and size (Rinne and Medina 1988). Similar to both the Rio de las Vacas and the Santa Fe area streams, both fish numbers and biomass generally decreased in the Mogollon Rim streams between 1985 and 1986 (table 3).

The utility of using contiguous, or paired, watersheds to delineate land management effects on riparian ecosystems is not absolute. Several years of data collection are prerequisite to establish a "reference point" for individual streams. Differential, historic, cumulative effects of the varying multiple uses potentially render even "across the divide" riparian areas to be in different states. The presence of "near pristine" watersheds, such as Pine Creek, provides an index or reference of potential natural condition and is invaluable for establishing research designed to determine the effects of management activity on the watershed.

Research Complexity

Basic requirements of scientific field research are control of variables in time and space, adequate design, replication of experiments, and a valid research area. The Rio de las Vacas study findings allude to the difficulty in achieving control and replication on National Forest lands, even on a single stream system. A researcher's inability to control the varying degrees of land uses precludes determining the differential impacts of these respective uses. Independent management of habitat by the Forest Service and the sport fishery (or hunting) by state natural resource departments further complicates the situation (Rinne 1988a).

Land use planning is an essential and functioning component of the National Forest Planning Act of 1976. However, well-designed studies conducted by the scientific method under one management plan can easily become invalidated by a change in management. Further, changes in land management plans by the Forest Service can be appealed by permittees. For example, recent efforts were made to cooperate with one forest in Region 3 to study the effects of grazing management changes on one allotment that encompasses three contiguous montane riparian-stream ecosystems. Limited pretreatment data on fishes were available and plans were in progress to minimally modify spatial aspects of the revised grazing plan by addition of one fence. The proposed plan and the overall design would have provided ample time for collection of additional pretreatment information. It was an excellent opportunity for valid research that potentially would produce much needed information for land managers. The permittee subsequently appealed the proposed changes and litigation became imminent. A researcher is always at risk in such a situation. Unfortunately, such litigation delays much needed research and management opportunity. Moreover, future management may be based on the results of the court's decision, which will be economically, socially, or financially based (Borman and Johnson 1990) rather than being based on ecology, biology, hydrology, or known best management practices for

riparian and fisheries resources. Ultimately, in such cases, the land manager, the researcher, and the natural resources all lose.

Natural Disturbance, Forest Management, and Research Opportunity

Often, natural disturbance events effect changes in the landscape that provide opportunities for the researcher. The Dude Fire is an example of such an opportunity. The Dude Fire resulted from lightning on June 25, 1990. More than 10,000 ha of forest burned in the watersheds of Dude, Bonita, and Ellison creeks. A multidisciplinary rehabilitation team was formed and immediate watershed rehabilitation was instituted through aerial seeding. Several small salvage timber contracts have been let. A two-year moratorium has been placed on grazing.

One of the team's charges was to draft a long-range plan for watershed rehabilitation and management in the aftermath of the fire. The long-term scope of the rehabilitation effort and its multidisciplinary philosophy, combined with more than three years of serendipitous pretreatment information on fish populations, aquatic macroinvertebrates, substrate fine content, and water quality, provided an unprecedented opportunity to examine the response of the riparian habitat and biota to wildfire and future land uses.

Fish population numbers and species were determined within a week after the fire and prior to the summer rainy season. No significant difference in fish populations occurred among the three streams immediately after the fire (table 5). Spot sampling in late July after flooding revealed no fish. Subsequent sampling throughout the stream courses in October 1990 and February 1991 documented only one adult (300 mm) brook trout in the headwaters of Dude Creek; effectively, fish have been eliminated from the three streams. Because trout are absent, re-introductions of fishes are proposed to (1) evaluate elevated water temperatures in June 1991, (2) determine flooding effects on fishes, (3) delineate flooding effects on fish food sources (aquatic macroinvertebrates), and (4) determine if immediate (July 1990) postfire quantity or quality of water was responsible for loss of fishes.

Analyses of water quantity and quality, and of aquatic macroinvertebrates will continue in the sub-Mogollon Rim streams affected and unaffected by the fire. Changes in stream morphology and sediment transport will be determined. The dynamics of woody organic debris disposition and movement through these systems and their effects on fish and their habitat will continue. Future grazing strategies conceivably will be designed to provide a setting for research (Rinne 1989, Szaro and Rinne 1988).

Opportunities for cooperative research and management efforts, such as those outlined above and in process of being initiated on the watersheds and in the riparian areas affected by the Dude Fire, conceptually will address some of the above suggested shortcomings to valid field research efforts, if management direction does not change. Multiyear pretreatment data are available. Timber harvest for many years to come has been removed for all practical purposes by the fire, and grazing has been suspended for several years by decree. Removal of these human-induced impacts for several years allows for evaluation of the response of both the watershed and riparian areas to natural events such as meteorology, geology, botany, and hydrology. Further, there is ample opportunity to later induce grazing design over a long term that would allow effective evaluation through separation of previous natural versus subsequently human-induced impacts on riparian areas.

Replication in most grazing studies has been done linearly in treatments (pastures) on the same stream (Rinne 1988a). Although such a design removes interstream variability, it is deficient in context of the functioning of stream ecosystems (Rinne 1989; Rinne and Medina, in press). That is, although the terrestrial components of treatments (pastures) are relatively confined and definable, the aquatic components are very dynamic. Water, its quantity and quality and stream biota can change frequently and quickly and are not delimited by strands of barb wire. This was well demonstrated in the Vacas study. The influences of spatial relationships of grazed stream reaches versus contiguous ungrazed reaches must be considered in designing research studies. If an interstream approach is necessary, grazing must be conducted only in downstream reaches. Fencing and ultimate grazing strategies based on watershed boundaries and in the more desirable interstream approach are both achievable objectives on the watersheds affected by the Dude Fire.

Other possible solutions to the dilemma of conducting viable, defendable research would be (1) to utilize existing experimental forests, or (2) designate land use management with research priority. Arizona contains

Table 5.—Comparison of the effects of fire on three trout populations (number fish/km), Mogollon Rim, central Arizona.

Date	Trout (number/km)		
	Dude	Bonita	Ellison
Prefire (1985–86)	360	440	400
Immediately postfire (7/9/90)	260	360	160
Three weeks later (7/25–26/90)	0	0	0
Autumn (10/23/90)	0	0	0
Winter (2/26/91)	1	0	0

two experimental forests, Sierra Ancha and Fort Valley. The Sierra Ancha has been subjected to previous experimental manipulation (Rich et al. 1961). The Fort Valley Experimental Forest does not lend itself to riparian fisheries research.

The second alternative (2 above), or designating special areas (allotments or watersheds) for research on National Forest lands, conceivably could provide areas for viable scientific examination of the effects of land use on riparian habitat and biota. These areas could function similar to the "Research Natural Area" concept. The Valle Vidal Unit on the Carson National Forest, northern New Mexico, was recently acquired by the Forest Service and is a prime example of such an area with great potential as a special management/research area. The Sandrock grazing allotment on the Apache Sitgreaves National Forest is another site where research and management could form an effective partnership to learn what benefits have accrued to riparian ecosystems as a result of more than a decade of grazing exclusion. The long-term rehabilitation and management plan for the Mogollon Rim stream complex following the Dude Fire, in practice, designates this drastically altered landscape as a special management/research area. Within such a management framework, pretreatment data are available, planning is possible, replication is achievable, and both invaluable short-term manipulative and reliable long-term watershed research can be conducted.

Partnerships between National Forest management and research suggested above could "set the arena" for invaluable study. Conceptually, the Tonto National Forest would mandate and ensure the carrying out of agreed-upon management over an acceptable period of time (5–10 years) and provide assistance in labor and funding to instrument watersheds and provide essential capital equipment. In turn, research collects, analyzes, and reports data that (1) defines functions and processes involved, (2) satisfies much needed forest monitoring information, and (3) has management implications.

The importance of long-term data for defining natural variability cannot be overstated. Research on a watershed deteriorated by domestic livestock grazing may require 10–20 years or even longer to begin to detect significant changes once a change in management direction is instituted (Platts and Rinne 1985). The present alternative to a controlled, long-term approach is to examine areas that have been differentially managed in a "case history approach." Such an approach (e.g., the Vacas) has some merit, but normally will result in only descriptive, subjective results that will ask more questions than are answered. Realistically, the case history approach will fail to delineate the interrelated processes that are functioning among a watershed, its land uses, and an affected stream ecosystem. Such an approach to research will not provide the land manager with reliable conclusions on which to base management decisions.

In summary, because of study brevity, lack of pretreatment information, and design flaws, case history intrastream approaches to study do not answer important questions relative to the effects of land management activities, their interactions with natural factors, and their effects on riparian ecosystems. Reliable answers will be better achieved with comprehensive, long-term, watershed (processes) approaches to research. "Frame of reference" (Likens 1985) or multiyear baseline data on streams within contiguous watersheds can then be used to design cooperative, interdisciplinary, replicable long-term research that results in valid, defendable results that can be used to manage forests on a "sustainable" basis for perpetuity.

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Two basic approaches to research design in riparian areas—intrastream and interstream—and their merits are evaluated based on physical, chemical, and biological data from streams in central Arizona and northern New Mexico. For effective generating of valid, defendable, and applicable information for future management of forest lands, a partnership (1) characterized by constant and intimate interaction of research and management personnel, (2) operating within the framework of daily forest land management activity, and (3) vigilant of research opportunity is proposed.

Keywords: Fisheries, research design, southwestern riparian-stream ecosystems

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Rocky Mountains

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The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

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